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The effect of global warming and urban heat islands on mortality, morbidity and productivity in The Netherlands

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Introduction

This paper constitutes a first attempt to quantify the economic impact of increased ambient temperature due to global warming and due to urban heat islands for The Netherlands. The study is limited to the direct effects of heat on humans: **mortality** (how many people die), **morbidity** (how many people enter hospital emergency care) and **productivity**. Please see Stone et al. [1] for the full details of this study.

Methods - Model Construction

Mortality

Based upon an analysis of meteorological data – daily averaged temperatures from 1995 until 2010 (source: KNMI- Royal Netherlands Meteorological office) – and statistics about deaths in the Netherlands (source: Statistics Netherlands) an empirical formula was derived that best estimated the relation between ambient temperature and mortality. This was multiplied with the value of a human life lost, with was set at 18 kEur/ year [2].

Equation:

$$M = (377 + (0.81 - 0.0511*T - 0.00389*T^2 + 0.00000964*T^4) * 38.73) * (18000/365))$$

with:	M	=	Mortality cost per day (Euro)
	T	=	The 24-hour averaged temperature (ºC)
	377	=	The average mortality per day (n/day)
	38.73	=	The standard deviation
	18000/365	=	Value of one day of life

The number of years lost before a natural death would occur was assumed to be 1 year.

Morbidity

Parsons et al. [3] have shown that in the United Kingdom, each °C rise in temperature above 18°C means an extra 0.36% of hospital admissions. Each °C lowering in temperature below 18°C means a drop in hospital admissions of 0.64%. It is assumed that these numbers can be applied to the Netherlands. In the Netherlands, the number of daily hospital admissions is about 11,000 (2838 per 10,000 inhabitants, source: Statistics Netherlands). The average costs associated with a hospital admission is about 5 KEur.

These costs were combined with the current average 24-hour temperatures and the average temperatures resulting from the several climate-scenarios to calculate the costs in the current and (possible) future climates. The difference between the current and future costs are the extra costs caused by climate change. Also this calculation is based on the assumption that the national pattern of hospital admissions with regard to average temperature will not change if the climate changes.

Equation when ambient temperature >18°C:

Mb = (11000 * 5000) + (T – 18) * 0.0036 * 11000 * 5000

Equation when ambient temperature <=18°C:

Mb = (11000 * 5000) + (18 - T) * 0.0064 * 11000 * 5000

with:	Mb	=	Morbidity cost per day (Euro)
	T	=	The 24-hour averaged temperature (ºC)
	11000	=	Average number of hospital intakes/day
	5000	=	Average cost of hospital uptake

Productivity

Not much is known about the effect of temperature on productivity. In a review written by Seppänen et al. [4], it was concluded that productivity within buildings drops when the temperature in the building rises above 25°C. This was adopted for our calculations.

Equation when ambient temperature <=25°C:

P = (469817 *10^3)/1800

Equation when ambient temperature > 25°C:

P = (469817 *10^3)/1800 – ((469817 *10^3)/180000) * T * 2 - 50

with:	P	=	Productivity per day (Euro)
	T	=	Corrected daily temperature (°C)
	469817 *10^3	=	Corrected national turnover of The Netherlands in Euro
	1800	=	Workable hours in a year

The temperature was assessed of a working day between 08:00 (am) and 18:00 (pm).

In order to calculate the costs, it is assumed that high temperatures outdoors lead to indoor temperatures just as high. Loss of productivity does not occur, or hardly occurs, at low temperatures, because Dutch buildings are generally properly heated. Not all production sectors suffer from loss of productivity because of heat, however. Therefore, all sectors in which the working pace and added value per unit of time are mostly determined by machinery (agriculture, forestry, fishery, mining, industry (textile, clothing, furniture and repair of machinery excluded), energy production, water companies, waste treatment, traffic (postal services and couriers excluded)) are not incorporated in the calculation. Also, the productivity calculation is limited to shops, services and health care production in buildings that are not equipped with any cooling installation. This was established by applying penetration degrees of cooling equipment in various types of buildings in the Netherlands. The remainder has an added value of MEur 469,817.

Results and Discussion

Global warming

The calculations provide a first estimation of the yearly damage by temperature increases caused by climate change as it is expected to occur in 2050 under four different scenario's [5], under the assumption that the economic and demographic structure of the Netherlands in 2050 is similar to the structure in 2010, and that the temperature related mortality and morbidity functions remain constant up to 2050. The numbers thus represent an order of magnitude and cannot be used in absolute terms. The results are shown in Table 1.

Table 1. Monetary damage by heat stress in MEuro / year.

Global Warming Scenario [5]	G	G+	W	W+
Mortality	-12	-16	-23	-25
of which is in July and August	1.3	2.7	3.7	8.7
Morbidity (hospital admissions)	-103	-137	-193	-249
of which is in July and August	-5	-1	2	14
Productivity losses	0	0	6	391

For both extra mortality and hospital admissions it seems that, under the assumptions used, global warming leads to a greater reduction of cases in wintertime, than it leads to a rise in mortality and hospital admissions during warmer summers. Therefore, the damage is 'negative' or, in other words, climate change will lead to a benefit in mortality and hospital admissions. The monetary gain is highest for hospital admissions.

Losses in occupational productivity occur, according to the applied calculation method, mostly in the W scenario (the W scenario assumes a 2°C rise in temperature in 2050, worldwide, compared to 1990). The (monetary) damage as a result of productivity losses increases rapidly in this scenario. Each 0.1°C above 25°C results in a loss of 0.5 MEur/h. We have used average daily temperatures for the calculations, which hide heat wave periods. It is expected that climate change will lead to more frequent and longer heat wave periods, which might mean that the effects of extreme temperatures in summer are underestimated.

Urban heat island effect

For the urban heat island effect, data were used of a meteorological station in Rotterdam Urban and compared to (rather) non-urbanised data for Rotterdam Airport in 2009. We followed roughly the approach advanced by Roodenburg [6]. The results are shown in Table 2. The presumption is that the entire Netherlands is either an urban heat island or a rural area.

It is clear that the urban heat island effect has a minor effect on mortality and morbidity costs, but leads to an enormous productivity decrease.

Table 2. Additional costs if The Netherlands would have been an urban heat island, compared to The Netherlands as a rural area (in MEuro/year).

	Urban Island compared to rural area
Mortality	-8
of which in July and August	-6
Morbidity (hospital admissions)	-25
of which in July and August	-20
Productivity losses	1480

Conclusions

Mortality in The Netherlands is higher in the cold than in the heat. The W+ scenario for global warming in The Netherlands (the worst case) would lead to a considerable reduction in mortality equivalent to about 25 MEuro due to early loss of life. Also, the cost related to hospital uptake would be about 250 MEuro less for scenario W+. The increase in summer temperature, however, would lead to a decreased productivity equivalent to about 390 MEur. The net effect of scenario W+ for global warming in The Netherlands would therefore be an additional cost of about 115 MEuro.

If The Netherlands would be one big city, the temperature profiles during the day are different than when The Netherlands would have been one rural area. Mortality and morbidity would be 8 and 25 MEuro less respectively of which about 80% is due to the months July and August only. In an urban environment, the productivity would decrease enormously because temperatures would be much higher during the day. The additional costs would be 1480 MEuro.

These numbers represent the result of a preliminary analysis using simplified functions based on available data. Future research is required to validate the functions and perform sensitivity analyses in order to substantiate the initial conclusions.

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